Chapter 9 Part 3

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Kinetic Molecular Theory

1. Gases consists of molecules whose separation is much larger than the molecules themselves
2. The molecules of a gas are in continuous, random, and rapid motion
3. The average kinetic energy of gas molecules is determined by the gas temperature, and all gas molecules at the same temperature, regardless of mass, have the same average kinetic energy
4. Gas molecules collide with one another and with the walls of their container, but they do so without loss of energy and no attractive or repulsive forces

Gas Motion

Kinetic Molecular Theory

Which of the following statements concerning kinetic molecular theory is true?

I. The average kinetic energy is determined by the mass and temperature of the gas molecules
II. Gas molecules are constantly in motion
III. Gas molecules lose energy upon collisions with the container

A. I
B. II
C. III
D. I & II

Molar Kinetic Energy

$$\overline{\mathrm{KE}} = \frac{3}{2}\mathrm{RT}$$

$$\mathrm{R} = 8.314\,\frac{\mathrm{J}}{\mathrm{mol\ K}}$$

- $\overline{\mathrm{KE}}$ is the average kinetic energy per mole of gas particles
- R is 8.314 J/(mol K)
- T is the temperature in Kelvin

Molar Kinetic Energy

Which of the following statements concerning the molar kinetic energy is true?

I. Gas molecules with higher masses, on average, have higher kinetic energy
II. Gas molecules with greater temperature, on average, have higher kinetic energy

A. I
B. II
C. Both I and II
D. Neither I nor II

Root mean squared (rms) velocity of gas particles

$$v_{\text{rms}} = \sqrt{\frac{3\text{RT}}{\text{MM}}}$$

$\frac{\overline{\text{KE}}}{2}$

R is 8.314 $\frac{\text{J}}{\text{K mol}}$

MM is the molar mass in kg/mol

Calculating rms speed

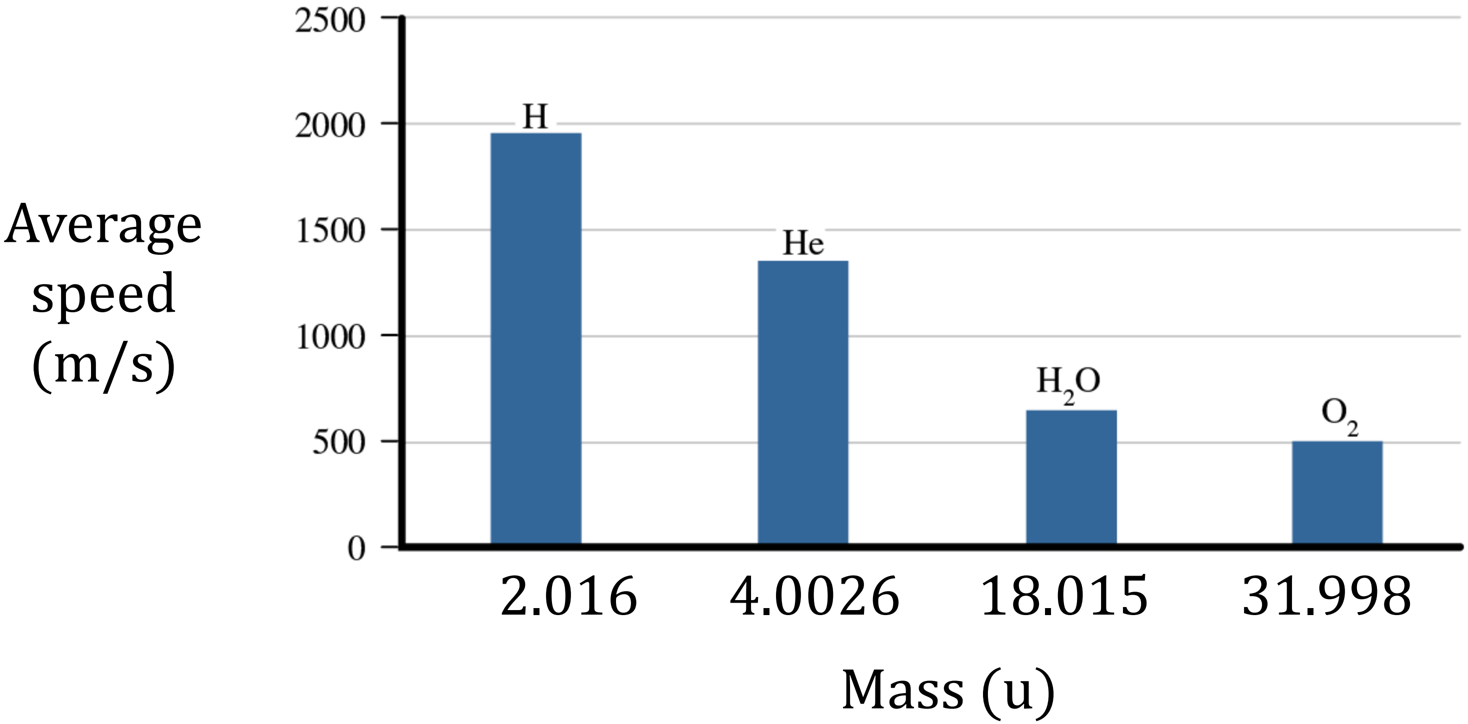
Calculate the rms speed of O_2 molecules in a cylinder at 21.00°C and 15.7 atm.

Increasing the molar mass at constant temperature

- Since kinetic molecular theory mandates that all gases at the same temperature must have the same kinetic energy, gases with smaller masses must move faster
- Thus, heavier gases move more slowly, on average, than lighter gases at the same temperature

$$v_{\text{rms}} = \sqrt{\frac{3\text{RT}}{\text{MM}}}$$

Speed of Gas Particles vs. Molar Mass



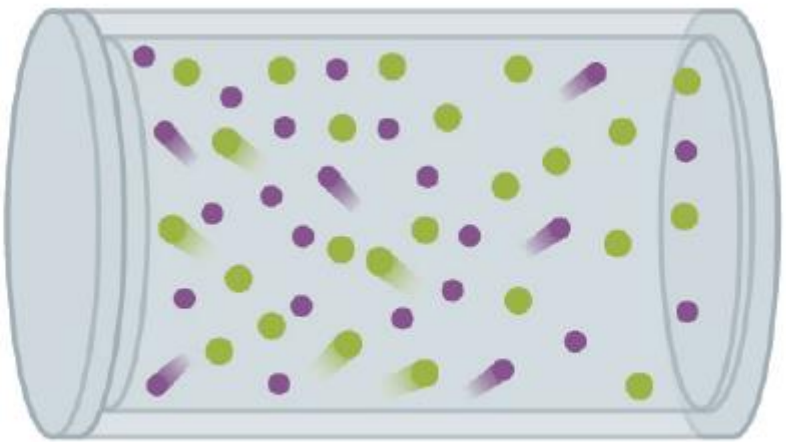
Molar mass, particle speed, temperature, and kinetic energy

Describe the relationship between the following pairs as directly or inversely proportional

A. $\overline{KE}$ and T
B. MM and v_{rms} (at constant T)
C. $\overline{KE}$ and v_{rms} (at constant MM)
D. MM and $\overline{KE}$ (at constant v_{rms})

Gas diffusion

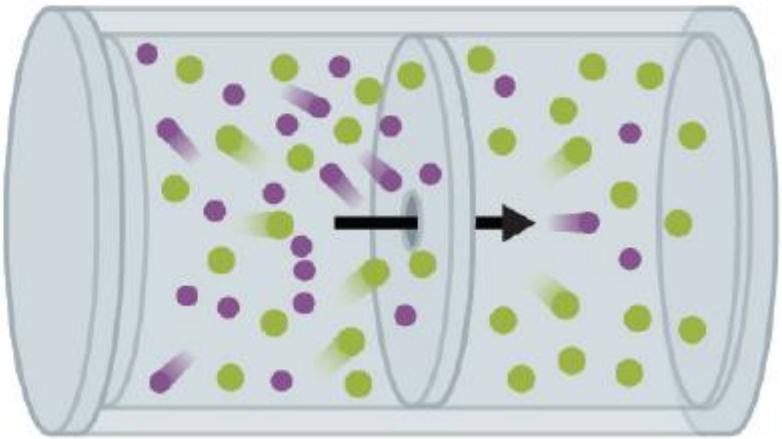
- Diffusion is the movement of one type of gas through another gas or vacuum



Diffusion

Gas effusion

- Effusion is the movement of gas molecules through a small opening into a vacuum



Effusion

Diffusion vs. Effusion

<u>DI</u>ffusion: has gasses <u>DI</u>spersing through one another

Effusion: the rate that gasses <u>E</u>scape through a small opening

Graham's Law of Effusion

$$\frac{\text{rate}_1}{\text{rate}_2} = \sqrt{\frac{\text{MM}_2}{\text{MM}_1}}$$

Rates of effusion

Calculate the ratio of effusion rates of molecules of carbon dioxide, CO_2, and sulfur dioxide, SO_2, from the same container and at the same temperature and pressure.

Effusion

Which of the following statements about Graham's Law of Effusion is true

I. Heavier gases effuse faster than lighter gases
II. The molar mass must be in units of kg/mol
III. The rate of effusion varies inversely with the square root of the molar mass

A. I
B. II
C. III
D. II & III

Real (Nonideal) gases

- Real gases are those which aren't ideal.
- No gases are truly ideal.
- There are three situation that weaken ideal gas behavior.
  - Large molar masses
  - High pressures
  - Low temperatures

Low temperature deviations

- At low temperatures, collisions between gas molecules can not be assumed to be elastic, and thus gases will likely interact for a short period after they collide
- This can cause clusters of particles to form, which decreases the total number of individual gas particles
- Thus, the theorized pressure (using the ideal gas law) of the gas is greater than the actual (measured) pressure

High pressure deviations

- Gases at high pressures have higher concentrations of gas molecules, which causes the gas molecules to be closer than they would be at lower pressures
- At these high pressures, gas molecules begin to occupy a significant amount of the container volume
- Since the theoretical volume of the container (by the ideal gas law) doesn't account for the size of the gas particles, it underestimates the volume of the container (which is the empty space plus the volume of the gas particles)

Behaviors that cause non-ideal gas behavior

- Gases behave less ideally with increasing molar mass
- Gases behave less ideally at lower temperatures
- Gases behave less ideally at higher pressures

van der Waals equation

For which of the following gasses would the correction for the volume component in the van der Waals equation be largest?

A. O_2
B. Cl_2
C. NH_3
D. XeF_4